State of Charge Verification of UN 3480 Lithium-ion Cells

Presented to: International Aircraft Materials & Systems Forum Meeting

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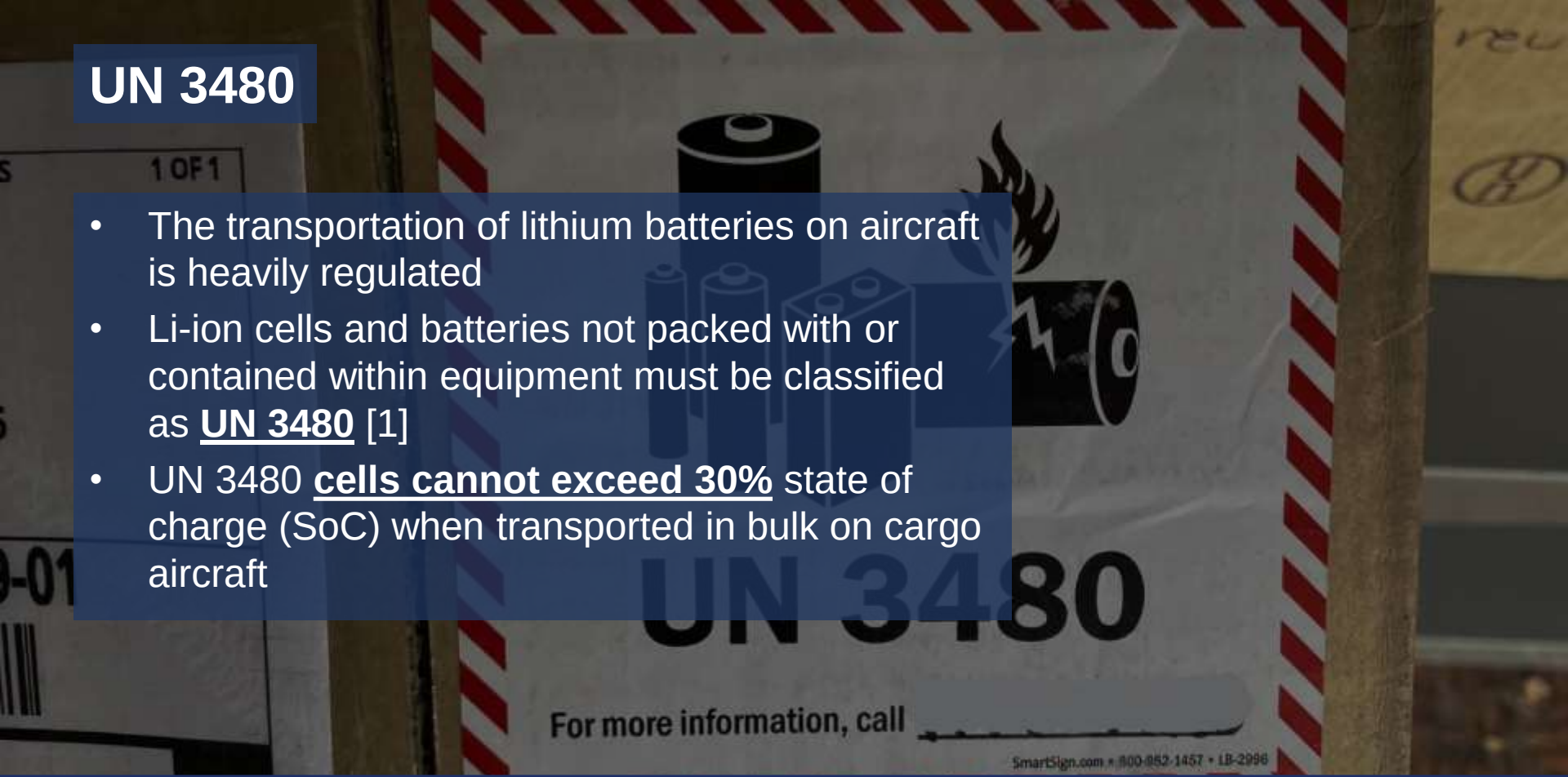
Date: April, 2024

Federal Aviation Administration

UN 3480

- The transportation of lithium batteries on aircraft is heavily regulated
- Li-ion cells and batteries not packed with or contained within equipment must be classified as **UN 3480** [1]
- UN 3480 **cells cannot exceed 30%** state of charge (SoC) when transported in bulk on cargo aircraft



[1] – https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-07/Lithium%20Battery%20Guide.pdf

Federal Aviation Administration

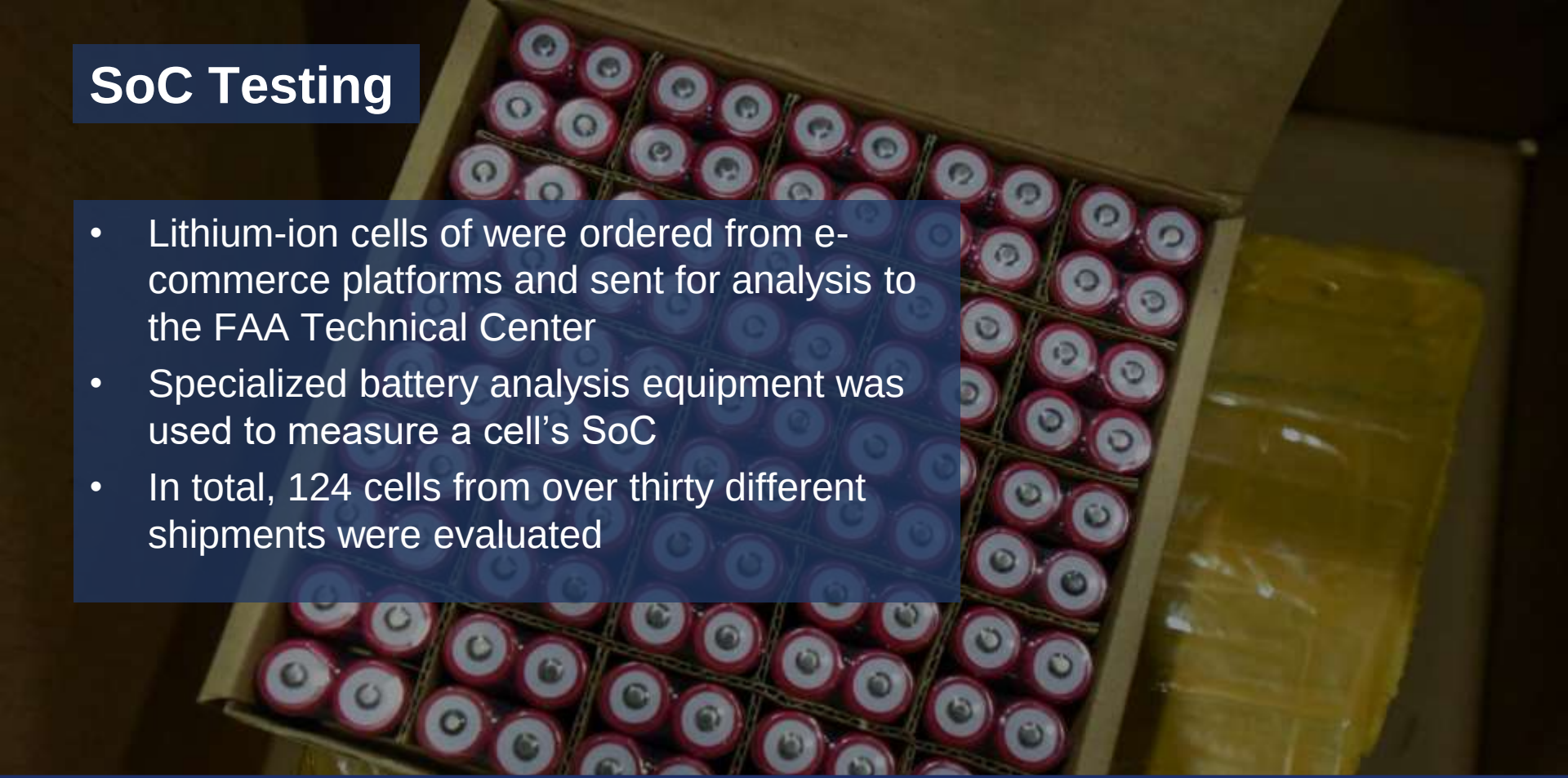
Why is SoC important?

- Batteries with a higher SoC are more likely to produce higher heat release rates, maximum temperatures and toxic gases during a thermal runaway event
- Cells are more likely to propagate to nearby cells/packaging at higher SoCs

30% **70%** **100%**

Peak reactions of batteries at various SoCs from past FAA testing

SoC Testing



- Lithium-ion cells of were ordered from e-commerce platforms and sent for analysis to the FAA Technical Center
- Specialized battery analysis equipment was used to measure a cell's SoC
- In total, 124 cells from over thirty different shipments were evaluated

Evaluated Cells

All types, chemistries and chemistries evaluated

Types	Chemistries	Sizes (Cylindrical Only)
Cylindrical	$LiCoO_2$	32650
Lithium Polymer (Pouch)	$LiFePO_4$	26650
	$LiMnCoO_2$	18700
	Unknown	18650
		18500
		14500
		10440

*Unknown - certain vendors did not list the cell chemistry

Assortment of evaluated cells

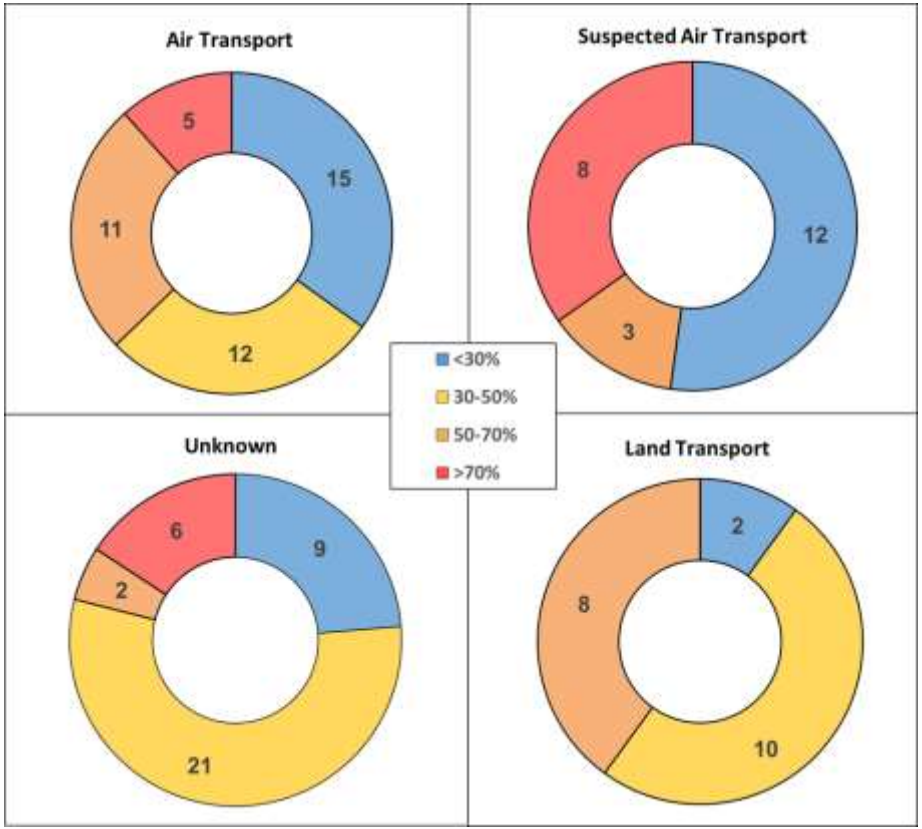
Transport Categorization

- Challenges in determining mode of transportation for many packages
  - Many did not have a tracking # listed or identifiable business address
  - Batteries were categorized based on the suspected mode of transport
- A sample size of 4-5 cells were tested per package, or less than that if the package contained <4

Confirmed Air Transport • Tracking # on package • Identifiable business address • Package shipped cross country within two days	**Suspected Air Transport** • No package tracking # • Identifiable business address • Package shipped cross country within two days
Unknown Transport • No package tracking # • Unidentifiable business address	**Confirmed Land Transport** • Tracking # available • Identifiable business address

Results

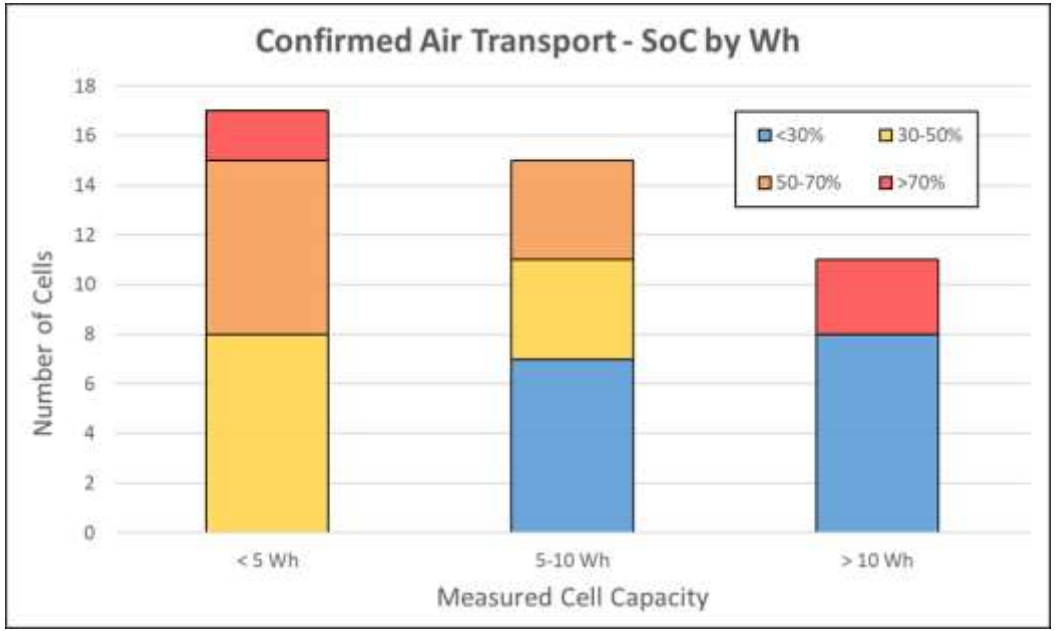
- Results were as follows:
  - Confirmed Air Transport: 65.1% (28 of 43) > 30% SoC
  - Suspected Air Transport: 47.8% (11 of 23) > 30% SoC
  - Unknown Transport: 76.3% (29 of 38) > 30% SoC
  - Land Transport: 90.0% (18 of 20) > 30% SoC
- Cells shipped by land **do not** have to abide by SoC restrictions
  - Data was still collected as air transportation could have been used if ordered from a different location



Measured SoC of cells by transport category

SoC of Cells Grouped by Energy Capacity

- Cells confirmed to have been shipped by air were further categorized based on their measured capacity
- Smaller capacity cells more likely to exceed 30% SoC
- Higher capacity cells less likely
  - One package of 16 Wh cells was shipped at over 90% SoC



Packaging Labels

- When shipped on aircraft, UN 3480 packages should have a:
  - UN “lithium battery mark” [2]
  - Cargo Aircraft Only (CAO)” label or text marking that the shipment is forbidden for transport aboard passenger aircraft [3]
- Of the nine packages confirmed to have been shipped by air, only:
  - 1 of 9 had a “lithium battery mark”
  - 0 of 9 had a CAO label

[2] – 49 CFR 173.185(c)(3)
[3] – 49 CFR 173.185(c)(1)(iii)

Package Mislabeling

- One evaluated package was mislabeled as UN3481
  - Contained one flashlight and fifteen spare cells, and thus should have been labeled as UN 3480
  - The allowable number of batteries for UN 3481 packages is limited to the number required to power the piece of equipment, plus two spare sets [4]

[4] – 49 CFR 173.185(c)(4)(vi)

Damaged and Improperly Packed Cells

- One package delivered by aircraft contained over 70 unprotected cells with no protective packaging
  - Cells could have made contact with terminals of the opposite polarity, leading to thermal runaway
- Many cells were observed to have been damaged
  - Significant signs of corrosion and swelling in many cells

Interior of package and underneath plastic wrap

Questions?

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